

Guide for Components of Robotic and Automatic Arc Welding Installations



American Welding Society



**AWS D16.2M/D16.2:2007
An American National Standard**

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American National Standards Institute
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Guide for Components of Robotic and Automatic Arc Welding Installations

3rd Edition

Supersedes AWS/NEMA D16.2/D16.2M:2001

Prepared by the
American Welding Society (AWS) D16 Committee on Robotic and Automatic Welding

Under the Direction of the
AWS Technical Activities Committee

Approved by the
AWS Board of Directors

Abstract

AWS D16.2M/D16.2:2007, *Guide for Components of Robotic and Automatic Arc Welding Installations*, provides performance recommendations for evaluating components of a typical robotic or automatic welding installation.

Emphasis is placed on the role of the welding interface. A pin arrangement and specific pin function for each location in a standardized 37-pin connector are proposed.



American Welding Society

550 N.W. LeJeune Road, Miami, FL 33126

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550 N.W. LeJeune Road, Miami, FL 33126

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Personnel

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*D. A. Wright, Sr.	<i>Zephyr Products, Incorporated</i>

*Advisor

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Foreword

This foreword is not a part of AWS D16.2M/D16.2:2007, *Guide for Components of Robotic and Automatic Arc Welding Installations*, but is included for informational purposes only.

The AWS Committee on Robotic and Automatic Welding was organized in 1985 to provide a centralized source for the exchange of technical information between manufacturers, installers, and operators of robotic and automated equipment. In 1988, the Committee was expanded to include representation of the Arc Welding Section of the National Electrical Manufacturers Association (NEMA). The relationship was formalized in September 1989 when the NEMA Codes and Standards Committee approved formation of a joint AWS/NEMA Committee to prepare a series of documents on various phases of the installation, maintenance, and operations of robots for welding.

The original edition of this standard, ANSI/AWS/NEMA D16.2-94, set guidelines for evaluating the performance of individual components that make up a typical robotic installation. Emphasis was placed on the standardization of the welding interfaces.

Since the publication of the second edition, AWS/NEMA D16.2/D16.M:2001, NEMA has officially withdrawn as a partner in this joint committee but continues in an advisory capacity through its representation on the D16 committee.

This third edition of D16.2 has been updated to include the latest terms and technology, and to meet the new AWS specifications for standards. Two informative annexes, one on sample maintenance schedule and one on sample spare parts list, were added to this guide. Revised areas are denoted by underlines or bars in the margin.

Comments and suggestions for the improvement of this standard are welcome. They should be sent to the Secretary, AWS D16 Committee on Robotic and Automatic Welding, American Welding Society, 550 N.W. LeJeune Road, Miami, FL 33126.

Official interpretations of any of the technical requirements of this standard may only be obtained by sending a request, in writing, to the Managing Director, Technical Services Division, American Welding Society (see Annex A). A formal reply will be issued after it has been reviewed by the appropriate personnel following established procedures.

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Table of Contents

	Page No.
<i>Personnel</i>	v
<i>Foreword</i>	vii
<i>List of Tables</i>	xi
<i>List of Forms</i>	xi
1. Scope	1
2. <u>Normative</u> References	1
3. Definitions	1
4. Arc Welding Power Sources	3
4.1 <u>Overview</u>	3
4.2 Continuous Duty	3
4.3 Remote Control	3
5. Arc Welding Torches and Accessories	3
5.1 <u>Overview</u>	3
5.2 Torch Design <u>Details</u>	3
5.3 Torch Holder <u>Details</u>	4
5.4 Collision Protection Device	4
5.5 Torch Accessories	4
6. Dereeling System	4
6.1 <u>Overview</u>	4
6.2 Equipment	4
6.3 Characteristics	5
7. Welding Interfaces	5
7.1 <u>Overview</u>	5
7.2 General Requirements	5
7.3 Input/Output Signal Requirements	5
8. Shielding Gas Delivery Systems	6
8.1 <u>Overview</u>	6
8.2 Regulators and Flowmeters	7
8.3 Fitted Hose Assemblies	7
9. Welding-Electrode Feeding Equipment	7
9.1 <u>Overview</u>	7
9.2 Service Conditions	7
9.3 Rating and Performance	7
9.4 Construction	7
9.5 Installation and Operation	8
10. Welding Circuit	8
10.1 Components	8
10.2 Design	8
10.3 Integrity	8
10.4 Conductor Size	8

10.5 Support Equipment Isolation	8
10.6 Methods of Weld Circuit Completions (Workpiece Leads)	8
11. Communication Control Wiring	9
11.1 <u>Design</u>	9
11.2 <u>Location</u>	9
12. System Grounding	9
12.1 Grounding Mechanics	9
12.2 Ground Identification	9
13. Cable and Hose Management	9
13.1 Routing	9
13.2 Voltage	10
13.3 Cable Fatigue	10
13.4 Extended Length	10
14. Maintenance	10
14.1 <u>Personnel</u>	10
14.2 Preventive Maintenance	10
14.3 <u>Spare Parts</u>	10
Annex A (Informative)—Guidelines for the Preparation of Technical Inquiries	11
Annex B (Informative)—Informative References	13
<u>Annex C (Informative)—Sample Maintenance Schedule for a Robot Arc Welding System</u>	15
<u>Annex D (Informative)—Sample Spare Parts List for a Robot Arc Welding System</u>	17
List of AWS Documents on Robotic and Automatic Welding	19

List of Tables

Table		Page No.
1	<u>Typical</u> Connector Pin Assignments	6
2	Minimum Hose Assembly Breaking Strength	7
<u>C.1</u>	<u>Sample Maintenance Schedule</u>	16
<u>D.1</u>	<u>Sample Spare Parts List</u>	18

List of Figures

Figure		Page No.
1	Typical Robotic Arc Welding Arrangement.....	2
2	Pin Layout for a Standard 37-Pin Connector (Ref. MS3102A-28-215).....	5
3	Typical Robot Welding Circuit	9
4	Protective Earth (Ground).....	10

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Guide for Components of Robotic and Automatic Arc Welding Installations

1. Scope

This document applies to the recommended design, integration, installation, and use of industrial welding robotic and automatic systems. This document is intended for the gas metal arc welding (GMAW) and flux cored arc welding (FCAW) processes. Pertinent parts may address additional welding processes.

Robotic and automatic arc welding systems consist of a manipulator, power source, arc welding torch and accessories, electrode feed system, dereeling system, shielding gas delivery system, welding circuit, shielding and communication control, and grounding system. There may be other accessories that are outside the scope of this document, such as safety devices and monitoring, joint-tracking, and vision systems. A typical system is illustrated in Figure 1.

This standard makes use of both the International System of Units (SI) and U.S. Customary Units. The measurements may not be exact equivalents; therefore, each system must be used independently of the other without combining in any way. The standard with the designation D16.2M:2006 uses SI Units. The standard designation D16.2:2006 uses U.S. Customary Units. The latter are shown within brackets [] or in appropriate columns in tables and figures.

Safety and health issues and concerns are beyond the scope of this standard and therefore are not fully addressed herein. Safety and health information is available from other sources, including, but not limited to, ANSI Z49.1, *Safety in Welding, Cutting, and Allied Processes*, and applicable federal and state regulations. Other safety documents are listed in Annex B.

2. Normative References

The following standard contains provisions which, through reference in this text, constitute provisions of this AWS standard. For undated references, the latest edition of the referenced standard shall apply. For dated

references, subsequent amendments to, or revisions of, any of these publications do not apply.

AWS Documents:¹

AWS A3.0, *Standard Welding Terms and Definitions*

3. Definitions

Terms used in this document are in accordance with AWS A3.0, *Standard Welding Terms and Definitions*. In addition, for the purposes of this document, the following definitions apply:

analog input. A dc voltage signal from the process equipment to the robot controller that may vary from 0 to 100% of the output range.

analog output. A dc voltage signal from the robot controller to the process equipment that may vary from 0 to 100% of the output range.

arc established. A discrete input signal indicating that a welding arc is present.

arc on/arc off. A discrete output signal that initiates or terminates the welding process.

continuous duty. The capability of a power source to operate 100% of the time without interruption and without exceeding the maximum temperature criteria of the insulation and components within the power source. In all cases, the required load should not exceed the weld power source rating for continuous duty.

discrete input. An on-off signal from the weld equipment to the robot controller to indicate the status of the function being monitored.

discrete output. An on-off command from the robot controller to the weld equipment used to control peripheral components.

¹ AWS standards are published by the American Welding Society, 550 N.W. LeJeune Road, Miami, FL 33126.

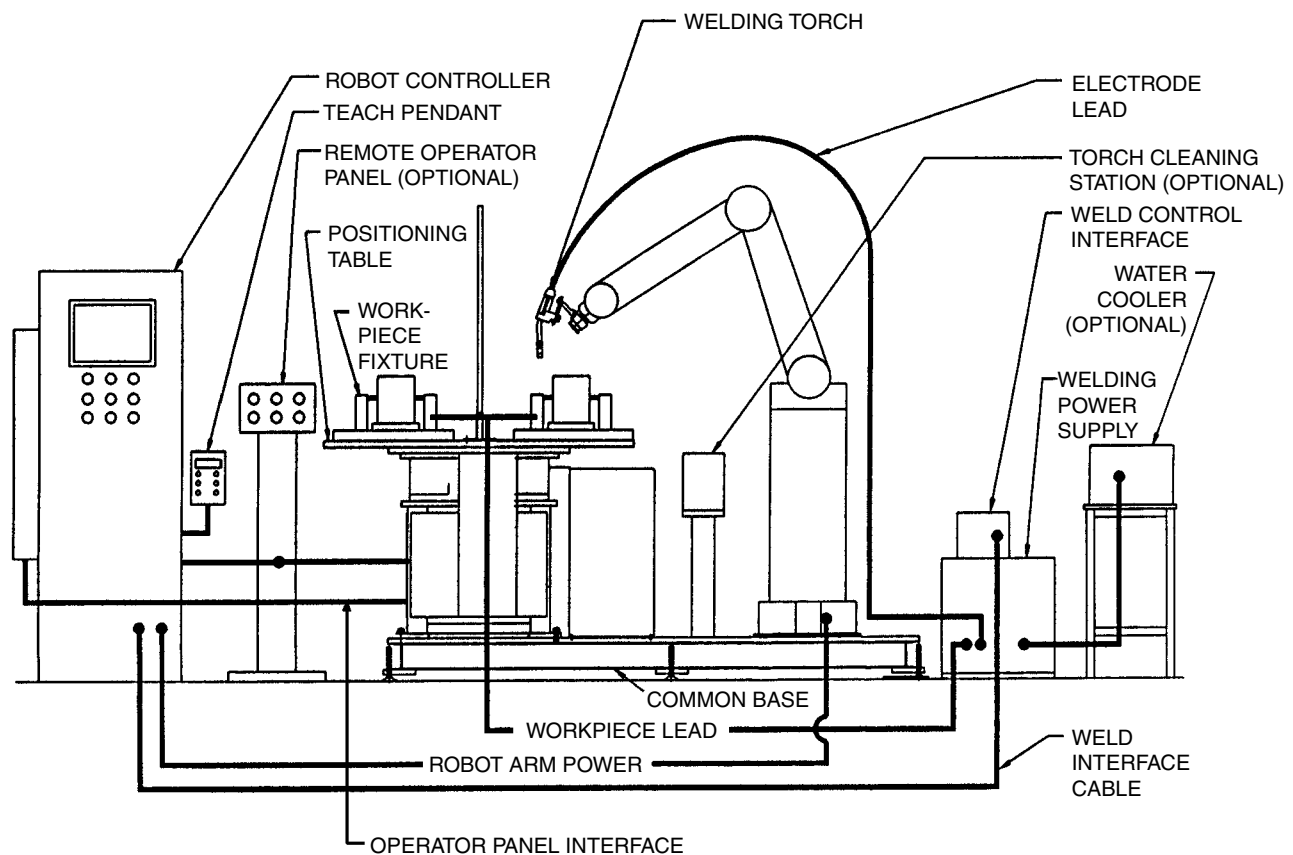


Figure 1—Typical Robotic Arc Welding Arrangement

electrical shield. An electrical component that acts as a barrier to electromagnetic fields by redirecting the energy.

electrode lead. The conductor between one of the welding power terminals of the arc welding power source and the welding electrode.

electrode stick check. A signal generated by the welding power source to indicate that the electrode has fused to the workpiece.

electrode touch. A signal generated by the welding power source to indicate that the electrode has contacted the workpiece.

emergency stop. The operation of a circuit using hardware-based components that overrides all other controls, reduces all mechanisms to a zero energy state, causes the cessation of all mechanical movement, and terminates the electrical welding output of the welding power source.

gas on. Discrete output signal used to turn on the gas solenoid, activate auxiliary equipment, or both.

load current. The amperage flowing in the welding circuit when a load is applied to the welding terminals.

load voltage. The voltage between the welding terminals of the arc welding power source when a load current is flowing in the welding circuit.

manipulator. The mechanism of a machine that usually consists of a series of segments jointed or sliding relative to one another used for grasping and/or moving objects usually in several degrees of freedom.

output enable. Discrete output signal for enabling all automatically controlled discrete output signals.

rated load voltage. The load voltage at rated output.

rated output. Consists of a designated limit of output or capacity expressed as a rated load voltage, rated load current, and rated load duty cycle when the power source

is operated at rated input voltage(s) and rated frequency(ies) or at rated speed.

tool center point (TCP). The point defined for a given application relative to the mechanical interface coordinate system.

welding circuit. All attachments connected to the welding terminals of the arc welding power source.

welding equipment status. Discrete input signal to monitor readiness of the welding equipment.

welding leads. The conductors that connect the welding power source to the workpiece and electrode.

welding terminals. The connectors of an arc welding power source which furnish welding power and, when provided, high-frequency energy for the welding arc.

welding torch. An apparatus that directs the placement of an electrode, plasma column or filler metal supplied as a continuous electrode and provides the means for supplying welding current and shielding gas as necessary.

weld voltage reference. A 0–10 volt output signal that controls the output voltage of the weld power source.

wire feed forward (robot controlled). Discrete output signal from the robot to initiate forward wire feed at a rate specified by the analog signal for the wire feed speed.

wire feed reverse (robot controlled). Discrete output signal from the robot to initiate reverse wire feed at a rate specified by the analog signal for the wire feed speed.

wire feed speed reference. A 0–10 volt output signal that controls the electrode wire feed rate.

4. Arc Welding Power Sources

4.1 Overview. This clause outlines the basic construction and performance requirements for arc welding power sources in robotic and automatic arc welding installations. Arc welding power sources used in robotic and automatic welding installations should be constructed and tested in accordance with NEMA EW-1, JIS, and International Electrotechnical Commission (IEC) 60974-1, *Requirements for Arc Welding Equipment, Part 1: Welding Power Sources*.

4.2 Continuous Duty. Arc welding power sources for robotic and automatic welding installations should be rated for continuous duty. See Clause 3 for the definition of continuous duty.

4.3 Remote Control. Arc welding power sources should have remote control capabilities for interfacing requirements. Refer to Clause 7, Welding Interfaces.

5. Arc Welding Torches and Accessories

5.1 Overview. This clause outlines the basic design and requirements for GMAW and FCAW torches used with robotic and automatic welding equipment.

5.2 Torch Design Details

5.2.1 Style. The welding torch size, style, and design should allow access to the weldment. The torch may be either air or liquid cooled, curved or straight, and should provide proper access and position relative to the weld joint.

5.2.2 Weight. The combined weight of the welding torch and other mounted components should not exceed the design limit as specified by the manufacturer for the welding manipulator.

5.2.3 Insulation. The exposed surfaces of the welding torch should be electrically isolated from the welding circuit. Such surfaces include the gas nozzle, torch body, and any other exposed surface not intended to carry welding current.

5.2.4 Mounting. Provisions for mounting the torch should be such that the tool center point (TCP) does not deviate from the system repeatability requirements.

5.2.5 Utilities. Utilities consist of shielding gas, coolant, current, and other commodities required for the process. All utility connections should be designed to aid proper installation (for example color coding, labeling, or variation of fitting size).

Cables and hoses should be of adequate length and flexibility so as not to restrict the movement of the manipulator or the supply of the utilities. Coiling of cables should be avoided to prevent induced noise, inductance, or voltage.

Utility cables should be supported with a counter balance or strain relief system to prevent excessive stress at connection points. Utility cables should be routed for protection, e.g., trays or racks.

5.2.6 Current Rating. All torches should meet NEMA EW-3, *Semiautomatic Wire Feed Systems for Arc Welding Electrode Feeding Equipment*. Torch specifications are typically based on 100% CO₂ gas. For gases other than 100% CO₂, the current rating should be rated in accordance with the manufacturer's specifications to meet continuous duty requirements.

5.2.7 Repeatability. Torches should be designed so maintenance minimizes the change of the electrode position with respect to the manipulator's tool center point (TCP). Part replacement should not change the electrode position.

5.3 Torch Holder Details

5.3.1 Mounting to Manipulator. The torch holder should have the proper mounting pattern or adapter to achieve a secure mounting.

5.3.2 Torch Attachment to Holder

5.3.2.1 The torch holder should provide electrical isolation between the torch and the manipulator end effector.

5.3.2.2 The torch holder should provide alignment capability of the torch.

5.3.2.3 The torch holder should be mechanically rigid to withstand a collision.

5.3.2.4 The torch holder should be able to accept the torch specified for the welding application.

5.4 Collision Protection Device

5.4.1 When a torch collision occurs, the collision protection/detection device should provide an electrical signal to the system controller.

5.4.2 The collision protection device should reposition the weld gun, after collision, to the original TCP to within ± 0.13 mm [0.005 in].

5.5 Torch Accessories. Torch accessories are devices that may be beneficial in robotic or automatic welding cells. Typical devices may include cleaning stations, water coolers,² alignment tools, and wire cutters.

5.5.1 Cleaning Stations

5.5.1.1 A cleaning station is an accessory that removes spatter from the torch. Torches should be cleaned periodically to prevent excessive accumulation of spatter that affects process performance. A cleaning station may also have the ability to apply anti-spatter compound after cleaning.

5.5.1.2 Cleaning stations, when employed, should not adversely affect the performance of the torch, wire, or system repeatability.

5.5.2 Water Cooler

5.5.2.1 A water cooler is an accessory sized to maintain the water-cooled welding torch at or below its maximum operating temperature at continuous duty as specified by the torch manufacturer.

² Water cooler is a common industrial term. The coolers consist of a reservoir and may contain a radiator. Coolants other than water may also be used.

5.5.2.2 When coolant flow is inadequate, a sensing device should provide an electrical signal to the system controller.

5.5.3 Torch Alignment Tools. Alignment tools should verify proper torch position relative to the robot wrist mounting flange. The alignment tool may have provisions for compensating for torch alignment.

5.5.3.1 Defining the Tool Center Point (TCP). The TCP relative to the welding torch must be accurately defined and maintained to ensure accurate placement of the welding electrode with respect to the component being welded. Follow the manufacturer's recommended procedures for initially defining the TCP.

5.5.3.2 TCP Maintenance. There are a number of methods available for measuring and maintaining TCP alignment. These methods consist of two major categories: Physical measurement/mechanical adjustment and TCP measurement/redefinition via software.

The most common method of physical measurement/mechanical adjustment is a torch alignment jig. In this case the torch is physically placed in the alignment jig where misalignment can be measured and if necessary physical adjustments can be made with tools built into the jig. This method of adjustment brings the torch back to the nominal physical shape and originally de-fined TCP location. This process is done manually and typically requires removal of the welding torch.

Another method of TCP maintenance is to measure the TCP offset and then redefine the TCP, via software, to match the new physical location. The TCP offset measurement means can be either contact or noncontact. This process can be done automatically with little to no impact on cycle times.

5.5.4 Welding Wire Cutters. Welding wire cutters should be used to establish uniform wire extension and profile.

6. Dereeling System

6.1 Overview. This clause outlines the basic requirements for conveying welding wire from the wire package (i.e., spools, payoff packs) of any size to the entrance of the wire feeder mechanism.

6.2 Equipment. The dereeling system should consist of the following: dereeling spool handler, braking system, auxiliary drive motors, conduit, guides, and cable retention.

6.3 Characteristics

6.3.1 The pulling force on the welding wire should typically not exceed 44 N [10 lbf] at the entrance to the wire feeder.

6.3.2 A wire control system should limit filler metal leaving the package to that required to prevent entanglement when the wire feeder is stopped. Entanglement should not occur regardless of the weight of the filler metal package or the wire feed speed. A braking system should be employed that prevents slack from occurring in the wire and therefore prevents tangling.

6.3.3 The dereeler should be designed and installed to provide for easy and safe loading of the wire package.

6.3.4 All dereeler components in direct contact with the welding wire should be isolated from the welding ground with a minimum resistance of 1 M Ω at 500 Vdc.

6.3.5 The spool should be properly secured to prevent unintended motion.

7. Welding Interfaces

7.1 Overview. This clause outlines the basic requirements for the interface between the robotic/automatic controller and the welding equipment. Some robots use fiber optic interfaces.

7.2 General Requirements. The interface should be provided by the standard connector, MS3102A-28-215.

The pin layout is shown in Figure 2. Typical connector pin assignments are shown in Table 1 and in 7.3. The interface should provide electrical isolation between the controller and the welding equipment as well as the necessary circuitry for converting the controller's input/output signals to a form usable by the welding equipment.

7.3 Input/Output Signal Requirements³

7.3.1 Analog Signals

7.3.1.1 Analog output(s) should provide an electrical control signal (Vdc). A typical control signal provides 0–10 Vdc. There should be four pins reserved for analog outputs for use as follows:

Pin Designation (may vary with system applications)

- (A) Wire feed speed reference (+)
- (B) Wire feed speed reference (common)
- (C) Weld voltage reference (+)
- (D) Weld voltage reference (common)

7.3.1.2 Analog input(s) should provide for an electrical feedback signal (Vdc). There should be four pins reserved for analog inputs for use as follows:

³ For the purposes of this document, the robot or automatic controllers are considered as the source of output signals and the receiver of input signals.

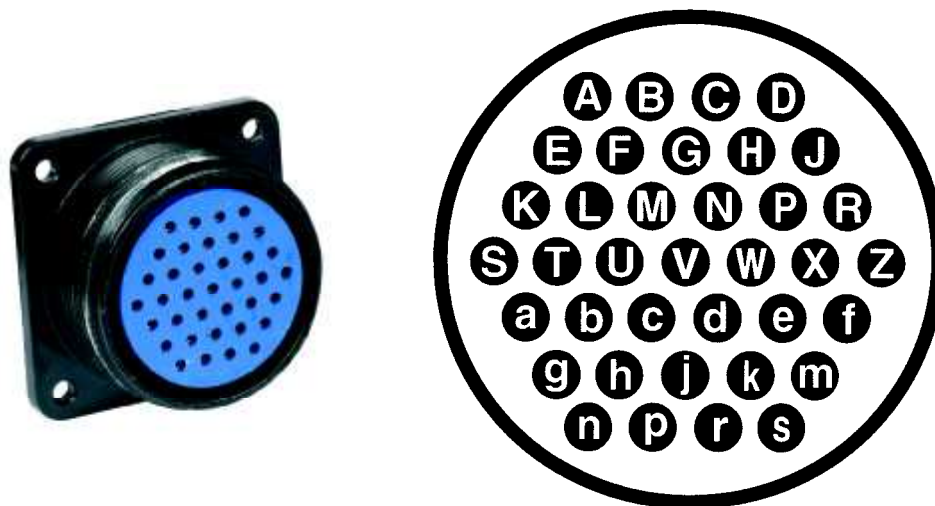


Figure 2—Pin Layout for a Standard 37-Pin Connector (Ref. MS3102A-28-215)

Table 1
Typical Connector Pin Assignments

Pin Location	Pin Function
A	Wire Feed Speed Reference (+)
B	Wire Feed Speed Reference (Common)
C	Weld Voltage Reference (+)
D	Weld Voltage Reference (Common)
E	Weld Current Feedback (+)
F	Weld Current Feedback (Common)
G	Weld Voltage Feedback (+)
H	Weld Voltage Feedback (Common)
J	Spare
K	Spare
L	Spare
M	Output Enable (Dry Contact)
N	Output Enable (Dry Contact)
P	Output Common
R	Arc On/Arc Off
S	Arc Voltage On
T	Wire Feed Forward—Possible Jog
U	Wire Feed Reverse—Possible Jog
V	Spare
W	Spare
X	Gas On
Z	Electrode <u>Stick Check</u>
a	Spare
b	Spare
c	Input Common
d	Arc Established
e	Electrode Touched
f	Arc Failure
g	Welding Equipment Status
h	Spare
j	Spare
k	dc Power Source (+)
m	Power Source Common
n	Emergency Stop (+) Terminal
p	Emergency Stop Common
r	Spare
s	Electrical Shield

Pin Designation (may vary with system applications)

- (E) Weld current feedback (+)
- (F) Weld current feedback (common)
- (G) Weld voltage feedback (+)
- (H) Weld voltage feedback (common)

7.3.2 Discrete Outputs

7.3.2.1 Discrete output(s) should provide for direct current volt signal (Vdc).

7.3.2.2 There should be nine pins reserved for discrete outputs for use as follows:

Pin Designation (may vary with system applications)

- (M, N) Output enable (Dry Contact)
- (P) Output common
- (R) Arc on/Arc off
- (S) Arc voltage on
- (T) Wire feed forward—possible jog
- (U) Wire feed reverse—possible jog
- (X) Gas on
- (Z) Electrode stick check

7.3.3 Discrete Inputs

7.3.3.1 Discrete inputs should be direct current volts (Vdc).

7.3.3.2 There should be five pins reserved for discrete inputs as follows:

Pin Designation (may vary with system applications)

- (c) Input common
- (d) Arc established
- (e) Electrode touched
- (f) Arc failure
- (g) Welding equipment status

7.2.4 Other. There should be fifteen pins reserved for other miscellaneous input/output functions as follows:

Pin Designation (may vary with system applications)

- (k) dc power source (+)
- (m) Power source common
- (n) Emergency stop (+) terminal
- (p) Emergency stop common
- (s) Electrical Shield
- (J, K, L) Spares
- (V, W) Spares
- (a, b) Spares
- (h, j) Spares
- (r) Spare

8. Shielding Gas Delivery Systems

8.1 Overview. Gas delivery systems should consist of, but are not limited to, regulators, flow meters, fitted hose, hose connectors, gas mixers, and solenoid valves.

8.2 Regulators and Flowmeters

8.2.1 Regulators or flowmeters should be capable of supplying the specified shielding gas in a continuously adjustable range of 5 L/min. [10 ft³/h] to the maximum required for the application for each welding torch.

8.2.2 Gas flow should be indicated by a flowmeter, with a minimum accuracy of $\pm 10\%$ of full scale reading.

8.2.3 Gas flow devices should be capable of supplying the required gas flow on a continuous duty basis.

8.2.4 Outlet pressure of the gas flow devices should not exceed 690 kPa [100 psi].

8.2.5 Outlet connections should conform to the requirements of Compressed Gas Association (CGA) Class 032, as specified in pamphlet E-1, *Standard Connections for Regulator Outlets, Torches and Fitted Hose for Welding and Cutting Equipment*.

8.3 Fitted Hose Assemblies

8.3.1 Hose Types, Grades, and Sizes. The types, grades and sizes of nonconductive rubber hose should be in accordance with current RMA-CGA IP7, *Specification for Rubber Welding Hose*. Grade R has a non-oil-resistant cover, and it is not recommended for use in areas where oil or grease may be encountered. All rubber hoses should be protected from ultraviolet radiation from the welding arc.

8.3.2 Pressure Capabilities. Fitted hose assemblies should be designed for a minimum operating pressure of 690 kPa [100 psi].

8.3.3 Physical Strength. The minimum pull strength for axial and right-angle pulling should be in accordance with pamphlet E-1 of the Compressed Gas Association (see Table 2). Leakage, breakage, puncture, and hose separation constitute failure.

Table 2
Minimum Hose Assembly Breaking Strength

Nominal I.D.		Axial Pull		Angle Pull	
mm	in	kg	lb	kg	lb
5	3/16	45	100	23	50
6	1/4	136	300	68	150
8	5/16	158	350	90	200
10	3/8	158	350	90	200

Source: CGA Pamphlet E-1, *Standard Connections for Regulator Outlets, Torches and Fitted Hose for Welding and Cutting Equipment*.

8.3.4 All hose connections to and from the valve should conform to the requirements of CGA Class 032.

9. Welding-Electrode Feeding Equipment

9.1 Overview. This clause details requirements for equipment to feed continuous welding electrodes.

9.2 Service Conditions

9.2.1 Should the user encounter service conditions classified as unusual in accordance with NEMA EW-3, *Semiautomatic Wire Feed Systems for Arc Welding*, the user should contact the equipment manufacturer for further recommendations.

9.2.2 Welding-electrode feeding equipment should be installed and operated in accordance with the National Electrical Code, federal, state, and local codes as applicable, the manufacturers' specifications, and applicable safety specifications, including ANSI Z49.1, *Safety in Welding, Cutting, and Allied Processes*.

9.3 Rating and Performance

9.3.1 Duty Cycle. Welding-electrode feeding equipment for robotic and automatic welding should be capable of operating at continuous duty. The continuous duty cycle rating should be determined by conducting performance rating tests as described in 9.3.2.

9.3.2 Rating and Performance Tests. Rating and performance tests should be conducted as described in the applicable clause of NEMA Standard EW-3, *Semiautomatic Wire Feed Systems for Arc Welding Electrode Feeding Equipment*.

9.3.2.1 Welding-electrode feeding equipment should be capable of withstanding continuous cycling of 4 seconds on and 2 seconds off for a minimum of 10 consecutive minutes.

9.3.2.2 The temperature of the internal components and external surfaces should not exceed those specified in the applicable clause of NEMA EW-3.

9.4 Construction

9.4.1 General Considerations. Welding-electrode feeding equipment may be housed within the welding power source, may be a single unit, or may be of modular construction to allow the controls to be mounted separately from the wire drive motor assembly. The equipment may have provisions for mounting a coil or spool of welding electrode or may pull the electrode from a separate source such as a dereeler or bulk package.

9.4.2 Mechanical Construction

9.4.2.1 The design, construction, and performance of the wire feeder frame, case, cabinet, or enclosure should conform to the requirements of the applicable clause of NEMA EW-3.

9.4.2.2 Motors for feeding of welding electrode wires should be designed with sufficient power to provide the force necessary to pull the welding electrode from the coil, spool, package or from dereeling equipment, and to deliver the electrode to the welding torch at the rated speed (see Clause 6).

9.4.2.3 Wire drive roll assemblies should be designed to drive the welding electrode in a smooth and uniform manner at the rated speed. The number and design of drive rolls should be suitable for the size and type of electrode. Auxiliary motors, wire straighteners, and drive roll assemblies may be required for certain applications.

9.4.2.4 The conduits for guiding and transmitting welding electrode should be designed specifically for the following:

1. To suit the electrode size and type,
2. To provide low wear and drag between the electrode wire and conduit, and
3. To provide electrical insulation between the electrode and personnel or equipment.

9.4.3 Electrical Construction. Electrical components, insulation, wiring, cables, and connections should be designed to the requirements of the electrical construction clause of NEMA EW-3.

9.4.4 Remote Control. Welding-electrode feeding equipment should have remote control capability and should be suitable for interfacing to the robot control, automatic welding control, or power source.

9.4.5 Input Voltage Rating. When the welding-electrode feeding equipment is not contained within the enclosure of the welding power source, the input voltage to the equipment should not exceed 120 Vac nominal.

9.5 Installation and Operation

9.5.1 Recommended Mounting of Equipment. Because of the wide variety of configurations and applications for robotic and automatic welding installations, it is not possible to define rigid rules for the use of welding-electrode feeding equipment. However, the following points are provided to guide the user.

9.5.1.1 The electrode drive-roll assembly should be located as close as practical to the welding torch. Auxiliary drive assemblies or push-pull feeding systems may

be required for applications that involve large wire packages, small diameter wires, long cable runs, or difficult to feed wires.

9.5.1.2 The welding electrode path from the dereeling equipment, spools, or coils to the wire feeder and from the feeder to the welding torch should be as short as practical. Conduits used to guide the electrode should be mounted and supported so that there are no sharp bends.

9.5.1.3 Wire guide conduits and other components and assemblies that are connected to, or may come in contact with, the welding power circuit should be electrically insulated to avoid injury to personnel or equipment.

10. Welding Circuit

10.1 Components. Typical components of the welding circuit consist of the electrode and workpiece leads, the output terminals of the power source, and the power source itself (see Figure 3).

10.2 Design. The welding circuit should be designed to reduce the effect of thermal, electric, and magnetic interference.

10.3 Integrity. The welding circuit should meet the requirements of local, state, and federal codes. Electrical connections in the weld circuit should be made with clean, bright, conductive metal surfaces.

10.4 Conductor Size. Welding leads should be maintained as short as practical. The conductor size should be in accordance with the local, state, and federal codes and the power source manufacturer's recommendations.

10.5 Support Equipment Isolation. All components utilized in the arc welding system that are not physically part of the weld circuit path may need to be electrically isolated from the circuit depending on the application and the manufacturer's recommendation. In high-frequency applications [Plasma Arc Welding (PAW) and Gas Tungsten Arc Welding (GTAW)], total isolation between the welding circuit and the system earth ground may be required.

10.6 Methods of Weld Circuit Completions (Workpiece Leads)

10.6.1 The workpiece lead should be fastened, using compatible metals, as close as practical to the point of arc initiation.

10.6.2 No connection should cause interruption to the continuity of the workpiece lead path.

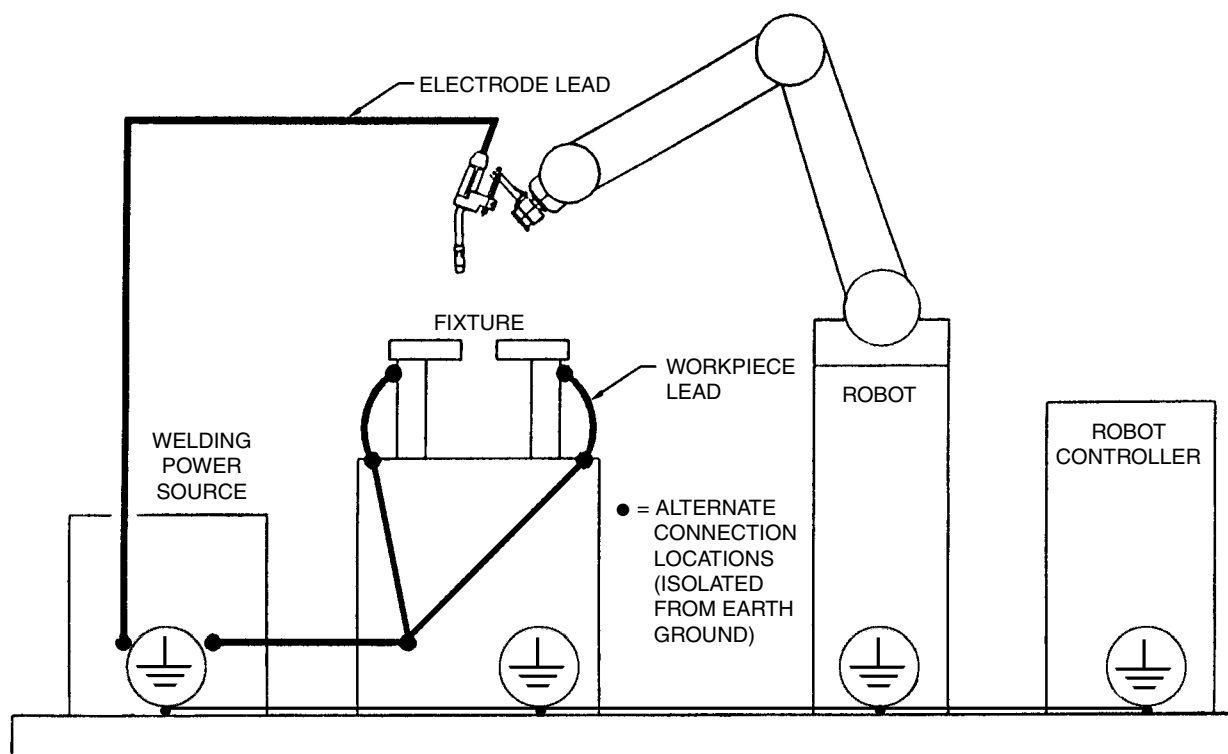


Figure 3—Typical Robot Weld Circuit

11. Communication Control Wiring

11.1 Design. All communication and control lines should be designed in accordance with local, state, and federal codes where applicable.

11.2 Location. Low-voltage discrete and analog signal lines should be segregated from ac discrete signal lines to prevent interference.

12. System Grounding

12.1 Grounding Mechanics. All exposed noncurrent carrying conductive parts, which might become energized under normal use and handling, should have a metal-to-metal contact and should be bonded to a common earth ground.

12.1.1 The system ground connection should be utilized for grounding purposes only.

12.1.2 The system ground connector should be sized in accordance with applicable federal, state, and local codes.

12.1.3 The system ground connection should be located as noted in Figure 3 or alternate location.

12.1.4 The system ground should be attached only by mechanical means. Solder alone should not be used as a means for ground connections.

12.2 Ground Identification. When the grounding means is an insulated lead, it should have a green colored surface with or without one or more yellow stripes. In all other cases, the grounding means should be identified by green coloring, by a legible marking with the green coloring, or by a legible marking with the symbols as shown in Figure 4, or alternatively with the letter(s) G, GR, GRD, GND, or GROUND.

13. Cable and Hose Management

13.1 Routing. Cable and hoses attached to movable devices (heads, etc.) should not be allowed to drag on the floor. Such cables and hoses should be contained within power tracks where applicable. All cables wires and hoses should be installed in an orderly fashion that prevents binding or pinching. Cables and hoses should not be allowed to protrude from the power rack.

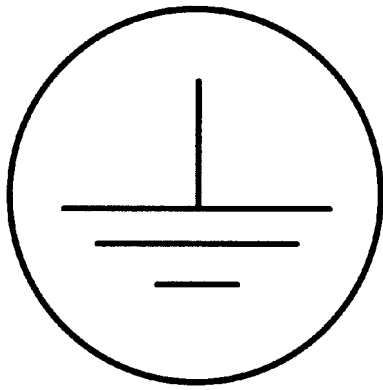


Figure 4—Protective Earth (Ground)

(Source: IEC 417; 5019)

13.2 Voltage. Low-voltage discrete and analog signal lines should be segregated from ac discrete signal lines to prevent interference.

13.3 Cable Fatigue. Cables and hoses should be supported with a strain relief to prevent excessive stress. Severe cycling of equipment can cause cable and hose fatigue.

13.4 Extended Length. Cables and hoses should be of appropriate length.

14. Maintenance

14.1 Personnel. Maintenance tasks should be performed only by personnel who have been properly trained for the

tasks, and who are familiar with the robot cell and its safe operation.

14.2 Preventive Maintenance

14.2.1 Preventive maintenance schedules should be provided by the robot manufacturer and/or the system integrator. Maintenance schedules for all equipment utilized in the work cell should also be provided. Maintenance schedules should be followed to ensure system repeatability and reliability. A sample maintenance list is shown in Annex C.

14.2.2 Supplementary preventive maintenance tasks specific to the work cell should be scheduled based on robot workload, tasks performed by the robot cell, and other equipment integrated into the work cell. This includes, but is not limited to, weld power supplies, positioning equipment, hydraulics, and pneumatics.

14.3 Spare Parts

14.3.1 The robot manufacturer should provide a list of recommended spare parts to stock on site. Spare parts lists for peripheral equipment should also be provided. A sample list of spare parts items is shown in Annex D.

14.3.2 Additions to the lists should be made based on the robots' tasks and the environment they are performed in, as well as peripheral equipment used in the robot cell. This includes, but is not limited to welding consumables, positioning equipment, pneumatics, and hydraulics.

14.3.3 Consideration should be given to lead times for ordering replacement parts such as major/minor bearings, motors, encoders, and drive amplifiers. The risk of lost time should be balanced against the cost of stocking spare parts.

Annex A (Informative)

Guidelines for the Preparation of Technical Inquiries

This annex is not a part of AWS D16.2M/D16.2:2007, *Guide for Components of Robotic and Automatic Arc Welding Installations*, but is included for informational purposes only.

A1. Introduction

The American Welding Society (AWS) Board of Directors has adopted a policy whereby all official interpretations of AWS standards are handled in a formal manner. Under this policy, all interpretations are made by the committee that is responsible for the standard. Official communication concerning an interpretation is directed through the AWS staff member who works with that committee. The policy requires that all requests for an interpretation be submitted in writing. Such requests will be handled as expeditiously as possible, but due to the complexity of the work and the procedures that must be followed, some interpretations may require considerable time.

A2. Procedure

All inquiries shall be directed to:

Managing Director
Technical Services Division
American Welding Society
550 N.W. LeJeune Road
Miami, FL 33126

All inquiries shall contain the name, address, and affiliation of the inquirer, and they shall provide enough information for the committee to understand the point of concern in the inquiry. When the point is not clearly defined, the inquiry will be returned for clarification. For efficient handling, all inquiries should be typewritten and in the format specified below.

A2.1 Scope. Each inquiry shall address one single provision of the standard unless the point of the inquiry involves two or more interrelated provisions. The provision(s) shall be identified in the scope of the inquiry

along with the edition of the standard that contains the provision(s) the inquirer is addressing.

A2.2 Purpose of the Inquiry. The purpose of the inquiry shall be stated in this portion of the inquiry. The purpose can be to obtain an interpretation of a standard's requirement or to request the revision of a particular provision in the standard.

A2.3 Content of the Inquiry. The inquiry should be concise, yet complete, to enable the committee to understand the point of the inquiry. Sketches should be used whenever appropriate, and all paragraphs, figures, and tables (or annex) that bear on the inquiry shall be cited. If the point of the inquiry is to obtain a revision of the standard, the inquiry shall provide technical justification for that revision.

A2.4 Proposed Reply. The inquirer should, as a proposed reply, state an interpretation of the provision that is the point of the inquiry or provide the wording for a proposed revision, if this is what the inquirer seeks.

A3. Interpretation of Provisions of the Standard

Interpretations of provisions of the standard are made by the relevant AWS technical committee. The secretary of the committee refers all inquiries to the chair of the particular subcommittee that has jurisdiction over the portion of the standard addressed by the inquiry. The subcommittee reviews the inquiry and the proposed reply to determine what the response to the inquiry should be. Following the subcommittee's development of the response, the inquiry and the response are presented to the entire committee for review and approval. Upon approval by the committee, the interpretation is an official

interpretation of the Society, and the secretary transmits the response to the inquirer and to the *Welding Journal* for publication.

A4. Publication of Interpretations

All official interpretations will appear in the *Welding Journal* and will be posted on the AWS web site.

A5. Telephone Inquiries

Telephone inquiries to AWS Headquarters concerning AWS standards should be limited to questions of a general nature or to matters directly related to the use of the standard. The AWS Board of Directors' policy requires that all AWS staff members respond to a telephone request for an official interpretation of any AWS standard with the information that such an interpretation can

be obtained only through a written request. Headquarters staff cannot provide consulting services. However, the staff can refer a caller to any of those consultants whose names are on file at AWS Headquarters.

A6. AWS Technical Committees

The activities of AWS technical committees regarding interpretations are limited strictly to the interpretation of provisions of standards prepared by the committees or to consideration of revisions to existing provisions on the basis of new data or technology. Neither AWS staff nor the committees are in a position to offer interpretive or consulting services on (1) specific engineering problems, (2) requirements of standards applied to fabrications outside the scope of the document, or (3) points not specifically covered by the standard. In such cases, the inquirer should seek assistance from a competent engineer experienced in the particular field of interest.

Annex B (Informative)

Informative References

This annex is not a part of AWS D16.2M/D16.2:2007, *Guide for Components of Robotic and Automatic Arc Welding Installations*, but is included for informational purposes only.

American National Standards Institute (ANSI)

ANSI Z49.1, *Safety in Welding, Cutting, and Allied Processes*, American Welding Society^{4,5}

American Welding Society⁶

AWS D16.1M/D16.1, *Specification for Robotic Arc Welding Safety*

AWS D16.3M/D16.3, *Risk Assessment Guide for Robotic Arc Welding*

AWS AWR, *Arc Welding With Robots: Do's and Don'ts*

AWS *Safety and Health Facts Sheets*⁵

Compressed Gas Association (CGA)⁷

CGA E-1, *Standard Connections for Regulator Outlets, Torches and Fitted Hose for Welding and Cutting Equipment*

⁴ ANSI Z49.1 is published by the American Welding Society, 550 N.W. LeJeune Road, Miami, FL 33126.

⁵ Available free of charge in electronic format from the American Welding Society web site.

⁶ AWS standards are published by the American Welding Society, 550 N.W. LeJeune Road, Miami, FL 33126.

⁷ CGA standards are published by the Compressed Gas Association, 4221 Walney Road, 5th Floor, Chantilly, VA 20151-2923.

International Electrotechnical Commission (IEC)⁸

IEC 60974-1, *Arc Welding Equipment—Part 1: Welding Power Source*

IEC 60974-5, *Arc Welding Equipment—Part 5: Wire Feeders*

IEC 60974-7, *Arc Welding Equipment—Part 7: Torches*

National Electrical Manufacturers Association (NEMA)⁹

NEMA EW-1, *Electric Arc Welding Power Sources*

NEMA EW-3, *Semiautomatic Wire Feed Systems for Arc Welding*

Robotic Industries Association (RIA)¹⁰

RIA 15.06, *American National Standard for Industrial Robot and Robot Systems—Safety Requirements*

Rubber Manufacturers Association (RMA)¹¹

RMA-CGA IP7, *Specification for Rubber Welding Hose*

⁸ IEC standards are published by the International Electrotechnical Commission (IEC), IEC Central Office, 3, rue de Varembe, P.O. Box 131, CH-1211 Geneva 20, Switzerland.

⁹ NEMA standards are published by the National Electrical Manufacturers Association, 1300 North 17th Street, Suite 1847, Rosslyn, VA 22209.

¹⁰ RIA standards are published by the Robotics Industries Association, 900 Victors Way, P.O. Box 3724, Ann Arbor, MI 48106.

¹¹ RMA standards are published by the Rubber Manufacturers Association, 1400 K Street, Suite 900, N.W., Washington, DC 20005.

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Annex C (Informative)

Sample Maintenance Schedule for a Robot Arc Welding System

This annex is not a part of AWS D16.2M/D16.2:2007, *Guide for Components of Robotic and Automatic Arc Welding Installations*, but is included for informational purposes only.

C.1 The following list in Table C.1 is an example of components of a robot system's maintenance schedule with examples of frequency. This list is intended as a guide and is not intended to be all-inclusive. Each robotic system user must make judgments on the items needed and the frequency that these items need to be checked or changed. This often is dictated by the arc

time required of the robot, the material being welded, and the type of equipment being used.

C.2 A proper maintenance schedule is important to minimize downtime and rework or scrap. Neglecting the system maintenance can be the difference between a successful and an unsuccessful robot application.

Table C.1
Sample Maintenance Schedule^a

TASK	DAILY	WEEKLY	MONTHLY	ANNUALLY
A. Welding Gun and Welding Equipment				
1. Change the contact tip	X			
2. Blow out the gun liner		X		
3. Change the gun liner			X	
4. Wipe off drive rolls		X		
5. Change drive rolls			X	
6. Inspect cables and hoses for damage		X		
7. Blow out welding wire conduits		X		
8. Check water level in circulator (water-cooled guns)		X		
9. Change welding wire conduits			X	
10. Clean out welding machine				X
B. Robot and Controller				
1. Verify that the torch alignment is correct	X			
2. Verify that the robot wrist is aligned			X	
3. Clean off controller		X		
4. Change batteries				X
5. Grease joints on robot arm				X
6. Clean out vents on control				X
C. Workcell				
1. Make sure that the lights are working		X		
2. Make sure that all welding lead connections are tight		X		
3. Check condition of sensors and switches		X		
4. Grease any gearboxes on positioner				X
5. Inspect mounting bolts for system components to make sure that they are tight				X
6. Inspect any cable carriers for damage			X	
7. Make sure that the safety components are working			X	
8. Lubricate any rotary welding lead connections using conductive lubricant recommended by the manufacturer		X		
D. Fixtures				
1. Make sure that the clamps are working correctly		X		
2. Inspect the locators for excessive wear		X		
3. Make sure that the welding lead connections are tight		X		
4. Check cables, hoses, and wiring for excessive wear			X	

^a Be sure to follow proper lockout and tag procedures before performing any maintenance.

Annex D (Informative)

Sample Spare Parts List for a Robot Arc Welding System

This annex is not a part of AWS D16.2M/D16.2:2007, *Guide for Components of Robotic and Automatic Arc Welding Installations*, but is included for informational purposes only.

D.1 The list in Table D.1 is an example of spare parts that could be kept for a robot system. The list is not intended to be all-inclusive, assumes one robot system, and does not include spare parts for any tooling that might be on the system. A separate list of spare parts would be needed. Several factors have an influence on the type and

quantity of spare parts which are: (1) the total number of robots, (2) the amount of downtime that can be tolerated, (3) the complexity of the robot system, and (4) the number of shifts per day that the robot is used. If downtime is critical, large items such as a spare robot arm and a spare power source can be kept as spare parts.

Table D.1
Sample Spare Parts List

ITEM AND DESCRIPTION	QUANTITY
A. Welding Torch	
1. Torch assembly	1
2. Torch gooseneck	2
3. Torch adaptor to wire feeder	1
4. Contact tips	100
5. Gas diffuser	10
6. Nozzles	20
7. Torch liners	3
8. Torch mount to robot	1
9. Adaptor plate for mount	1
10. Collision sensor (if used)	1
B. Welding Equipment	
1. Set of drive rolls for the wire feeder	1
2. Wire guides for the wire feeder	1
3. Wire feeder control cable	1
4. Water circulator (water cooled guns)	1
5. Water flow switch (water cooled guns)	1
6. Wire feeder control cable	1
7. Welding wire conduit (if needed)	1
8. Spare wire feeder	1
9. Spare power source	1
10. Ground brushes or rotary ground and connections	1
C. Robot Equipment	
1. Teach pendant cable	1
2. Teach pendant	1
3. Fuses for robot control	3 of each type
4. Grease for robot joints (see robot manufacturers recommendations)	2
D. System Equipment	
1. Spare lights and buttons	1 of each type
2. Cutter for reamer (if used)	1
3. Containers of anti-spatter spray	2
4. Light curtain or safety mat	1 of each type
5. Spare cables for a light curtain or safety mat	1
6. PLC (if used)	1
7. Operator screen if used	1
8. Spare fuses and relays for electrical cabinet	3 of each type
9. Spare limit switches or proximity switches	2 of each type
10. Spare switch cables	1 of each type
11. Air valve	1
12. Filter regulator	1

List of AWS Documents on Robotic and Automatic Welding

Designation	Title
D16.1M/D16.1	<i>Specification for Robotic Arc Welding Safety</i>
D16.2M/D16.2	<i>Guide for Components of Robotic and Automatic Arc Welding Installations</i>
D16.3M/D16.3	<i>Risk Assessment Guide for Robotic Arc Welding</i>
D16.4M/D16.4	<i>Specification for the Qualification of Robotic Arc Welding Personnel</i>
AWR	<i>Arc Welding With Robots: Do's and Don'ts</i>

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